RF exposure test exclusion analysis for 60GHz radio

Summary

This rf exposure analysis to justify compliance with rf exposure limits for the 60GHz transmitter was subject to FCC guidance through the FCC KDB system. The combination of this analysis, the system design that ensures that the two 60GHz transmitters only operate when audio accessory and phone are connected together via a proprietary interface, the tight coupling between the two device with minimal leakage fields outside of the phone-audio accessory interface, and the relatively low SAR values for other transmitters within the phone, where considered appropriate to address rf exposure compliance.

This document presents analysis to justify test exclusion for RF exposure evaluation for the SB6212 transmitter operating in the handset together with the SB6213 transmitter operating in the audio accessory in the docked configuration.

Phone: 2ALBB-A11

Audio accessory: 2ALBB-J1

Method for estimation of worst case power density

The dimension of the transmit antenna for both SB6212 and SB6213 is 1.7x1.4mm.

The aperture area in this case is less than 1cmx1cm so the worst case power density averaged over a $1cm^2$ area may be estimated conservatively as the power available from each antenna, after accounting for antenna losses, divided by $1cm^2$.

Estimation of power available from each antenna

We use two independent methods to provide an estimate of the power available from each transmit antenna after accounting for antenna losses. Consistency between the results from the two independent methods demonstrates the validity of the results.

Definition of symbols

Symbol	Description	Units
Pcond	Transmitter conducted output power (before accounting for antenna losses)	dBm
η	Antenna radiation efficiency	dB
Prad	Transmitter output power (after accounting for antenna losses) or total radiated power	dBm
D	Antenna far-field directivity	dBi
EIRP	Far-field equivalent isotropic radiated power	dBm

Method 1: Simulation based

Nominal PA conducted output power is determined by transistor level simulation. Antenna radiation efficiency is determined by electromagnetic simulation. The total radiated power from the output of the antenna after accounting for antenna losses is calculated as the sum of the PA conducted output power and the antenna radiation efficiency.

$$\text{Prad(sim)} = \text{Pcond(sim)} + \eta\text{(sim)} \qquad (1)$$

Method 2: Measurement based

Far-field EIRP is measured for the transmitter IC in a standalone configuration without enclosure. The transmit antenna directivity, also in standalone configuration without enclosure and in the far-field, is determined by electromagnetic simulation. The nominal total radiated power at the output of the antenna is calculated as the measured EIRP minus the directivity.

$$\text{Prad(meas)} = \text{EIRP(meas)} - \text{D(sim)} \qquad (2)$$

The standalone EIRP measurements are taken from the FCC report for FCC UK2-MOD621X.

Calculation for SB6212 (Method 1)

quantity	symbol	value	units	source
conducted power	Pcond	-1.9	dBm	transistor level simulation
radiation efficiency	η	-6.8	dB	electromagnetic simulation
total radiated power (nominal)	Prad (sim)	-8.7 0.135	dBm mW	calculated as Pcond+η
directivity	D	6.4	dBi	electromagnetic simulation
calculated EIRP	EIRP(sim)	-2.3	dBm	calculated as Prad+D
measured EIRP	EIRP(meas)	-3.5	dBm	standalone test report
difference	-	-1.2	dB	EIRP(meas)-EIRP(sim)

Table 1: Calculation of SB6212 nominal total radiated power from simulated conducted power and radiation efficiency

Calculation for SB6213 (Method 1)

quantity	symbol	value	units	source
conducted power	Pcond	-1.9	dBm	transistor level simulation
radiation efficiency	η	-5.1	dB	electromagnetic simulation
total radiated power (nominal)	Prad (sim)	-7.0 0.200	dBm mW	calculated as Pcond+η
directivity	D	6.9	dBi	electromagnetic simulation
calculated EIRP	EIRP(sim)	-0.1	dBm	calculated as Prad+D
measured EIRP	EIRP(meas)	0.4	dBm	standalone test report
difference	-	0.5	dB	EIRP(meas)-EIRP(sim)

Table 2: Calculation of SB6213 nominal total radiated power from simulated conducted power and radiation efficiency

Calculation for SB6212 (Method 2)

quantity	symbol	value	units	source
measured EIRP	EIRP(meas)	-3.5	dBm	standalone test report
directivity	D	6.4	dBi	electromagnetic simulation
total radiated power (measured)	Prad (meas)	-9.9 0.102	dBm mW	calculated as EIRP-D
total radiated power (simulated)	Prad (sim)	-8.7	dBm	Table 1
difference	-	-1.2	dB	Prad(meas)-Prad(sim)

Table 3: Measurement of SB6212 total radiated power from measured EIRP and simulated directivity

Calculation for SB6213 (Method 2)

quantity	symbol	value	units	source
measured EIRP	EIRP(meas)	0.4	dBm	standalone test report
directivity	D	6.9	dBi	electromagnetic simulation
total radiated power (measured)	Prad (meas)	-6.5 0.224	dBm mW	calculated as EIRP-D
total radiated power (simulated)	Prad (sim)	-7.0	dBm	Table 2
difference	-	0.5	dB	Prad(meas)-Prad(sim)

Table 4: Measurement of SB6213 total radiated power from measured EIRP and simulated directivity

Calculation of worst case power density

Spatially averaged power density

Both SB6212 and SB6213 transmitters are active simultaneously. So a conservative upper bound on the spatially averaged power density is the sum of the total radiated power from both SB6212 and SB6213, after allowing for antenna losses, divided by the applicable spatial averaging area of 1cm². Since the calculations above are based on nominal transmitter output power, we allow a further 2dB additional tune-up tolerance to provide a conservative estimate of worst case transmit power density (Table 5).

Quantity	Method 1	Method 2	Units	Source
nominal total radiated power SB6212	0.135	0.102	mW	Table 1/Table 3: Measurement of SB6212 total radiated power from measured EIRP and simulated directivity
nominal total radiated power SB6213	0.200	0.224	mW	Table 2/Table 4: Measurement of SB6213 total radiated power from measured EIRP and simulated directivity
sum of nominal total radiated power	0.33	0.33	mW	Sum of previous two rows
tune-up tolerance	2 1.58		dB linear units	SB6212/SB6213 IC datasheet
sum of maximum total radiated power	0.53		mW	sum of nominal total radiated power multiplied by tune-up tolerance in linear units
applicable spatial averaging area	1		cm²	
worst case spatially averaged power density	0.53		mW/cm²	sum of total radiated power divided by applicable averaging area
limit	1		mW/cm²	

Table 5: Calculation of spatially averaged power density

Spatial peak power density

In the internal gap between the two transmitters, the location of maximum spatial peak power density due to each transmitter occurs directly in front of the antenna aperture and may be approximated by the total transmitter power of that individual antenna, after allowing for antenna losses, divided by the antenna aperture area.

To estimate the maximum spatial peak power density, we therefore take the larger of the two total radiated powers between the two transmitters and divide that power by the common antenna aperture area (Table 6). No limit is applicable to the spatial peak power density.

Quantity	Method 1	Method 2	Units	Source
nominal total radiated power SB6212	0.135	0.102	mW	Table 1/Table 3: Measurement of SB6212 total radiated power from measured EIRP and simulated directivity
nominal total radiated power SB6213	0.200	0.224	mW	Table 2/Table 4: Measurement of SB6213 total radiated power from measured EIRP and simulated directivity
nominal total radiated power of the stronger transmitter	0.200	0.224	mW	Maximum of the previous two rows
nominal total radiated power of the stronger transmitter using the more conservative estimation method	0.224		mW	Maximum of the two columns
tune-up tolerance	2 1.58		dB linear units	SB6212/SB6213 IC datasheet
worst case total radiated power of the stronger transmitter	0.354		mW	nominal total radiated power of the stronger transmitter multiplied by tune-up tolerance in linear units
antenna aperture area	0.0238		cm^2	0.17cm*0.14cm
worst case spatial peak power density	14.9		mW/cm^2	worst case total radiated power of the stronger transmitter divided by antenna aperture area
limit	No applicable limit			

Table 6: Calculation of spatial peak power density

Conclusion

The calculated worst case spatially averaged power density of $0.53mW/cm^2$ would be approached within the internal transmit gap and, according to the calculation above, complies with the limit for maximum permissible exposure even at this worst case internal location.

The actual exposure condition external to the enclosure is from fields off the sides of the antennas and the power density at those external locations would be substantially less than this upper bound.

Thus the system satisfies the requirement with margin sufficient that no further near field testing is required. RF exposure test exclusion was approved in the FCC KDB inquiry response which is submitted as long-term confidential exhibit